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Advanced Materials for Fuel Cells

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Abstract

The ability to cheaply and cleanly produce electricity is the basis for economic competitiveness in today's world. During the next 15 years, both the U.S. and global markets will see a significant demand for new generating capacity. Fuel cells are expected to compete in this market, and offer significant benefits in the areas of emissions, high-quality power, distributed power, remote site operation, and linkage to biomass gas sources. However, fuel cells must offer competitive cost of electricity, comparable capital costs, and comparable reliability. The recent advance in fuel cell systems of linking either a molten-carbonate (MCFC) or solid-oxide (SOFC) with a gas turbine, apparently offers a significant efficiency benefit compared to other power systems. To compete effectively, fuel cell manufacturers must address a number of technical issues, including reduced manufacturing costs, reliability/monitoring/inspection, and higher-temperature materials for both the stack and for use in the combined fuel cell-turbine systems. BIRL, Northwestern University's industrial research laboratory, and NU faculty are actively involved in projects to address many of these technical hurdles.

MCFC Issues

MCFC systems have reached the large demonstration stage, with 250KW to 2MW systems in, or scheduled for, demonstration in the near term. Cost reduction issues for a number of components in the stack are still important to achieving competitive system costs. Other technical barriers include corrosion of the electrodes, current collectors, and seals, the thermomechanical stability of the electrolyte and stack over time, and corrosion resistant electrodes. We have led a number of projects to address these issues. For example, Prof. Olson and Dr. Kuehmann have developed an iron-based superalloy for high-pressure steam turbines on a project sponsored by EPRI. In their work, they utilize a thermodynamic-based model to design a material and processing route that delivers the necessary properties (physical, mechanical, and cost). This approach has been initially applied to the problem of separator plate alloys. To adequately address cost reduction for MCFC, materials, processing and yields must all be considered. Significant cost benefits could be realized by reducing the cycle time for tape-cast electrode/electrolyte layers, increasing the fabrication speed, and eliminating the nickel-cladding from the separator plate. Optimizing the design of the fuel cell stack to utilize the minimum amount of material which provides the desired life and reliability is also important to commercialization, and we are fully equipped to measure thermomechanical properties of these materials and characterize the micro structural changes over time.

SOFC Issues

The development of SOFC systems is not as advanced as MCFC, but they are still projected to reach market entry in the next 5 to 10 years. SOFCS are being pushed into two different operating temperature regimes; below 800°C where conventional metal alloys can be used, and above 10OO°C to integrate more efficiently with the gas turbine. Operating SOFCS below 800°C presents a number of problems, including lower power densities, increased ohmic resistances, and somewhat reduced efficiencies, Recently, Prof. Barnett has demonstrated a novel SOFC electrolyte which markedly reduces ohmic losses to as low as 500°C. In cell tests at 600°C he has achieved power densities of approximately 200 mW/cm^2. Reducing the manufacturing cost of the YSZ electrolyte is a key step toward SOFC commercialization, and Dr. Bernecki has shown that a modified thermal spray process can be used to deposit 10 μm YSZ layers on 50°/0 porous substrates. Initial tests with these coatings have shown good performance, and this method may be an attractive alternative to tape-casting or roll-forming.

Monitoring and Inspection

The ability to monitor and inspect the fuel cell components ***in situ*** with non-destructive methods, during both fabrication and service, is seen as an important step in meeting cost and reliability goals, Our current emphasis on intelligent process control for coatings and composites, monitoring of structures during service, and development of vision, capacitive/inductive, and acoustic emission inspection systems is directly transferable to many aspects of fuel cell development and demonstration.

Acknowledgment

The work discussed in this abstract has been sponsored by numerous agencies, consortia, and industrial partners, including GRI, EPRI, NSF, B&W, and M-C Power.